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SPECIAL SUPPLEMENT

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Stents Don't Require Systemic Anticoagulation....But the Technique (and Results) Must be Optimal

Issam Moussa, MD, Carlo Di Mario, MD, Lucia Di Francesco, PhD, Bernhard Reimers, MD, Simonetta Blengino, MD, Massimo Ferraro, RT, Antonio Colombo, MD

Preliminary Results of the MUST Trial

Marie-Claude Morice, MD

Adjunctive Antithrombotic Therapy with Stents, Current Status and Future Prospects

Stephen Fredd, MD

Preliminary Results of the Music Study

Peter de Jaegere, MD, Harald Mudra, MD, Hans Figulla, MD, Yaron Almagor, MD, Serge Doucet, MD, Ian Penn, MD, Antonio Colombo, MD, Christian Hamm, MD, Antonio Bartorelli, MD, Martin Rothman, MD, Masakiyo Nobuyoshi, MD, Tetsu Yamaguchi, MD, Vasilis Voudris, MD, Carlo diMario, MD, Serge Makovski, MD, Christian Hausmann, MD

Transradial Coronary Stenting: A Passing Fad or Widespread Use in the Future?

Jean Marco, MD, Jean Fajadet, MD, Bernard Cassagneau, MD, Christian Jordan, MD

A Progress Report from BENESTENT II: Heparin Coating, Restenosis and Cost-Effectiveness

Patrick Serruys, MD

PTA and Stents in the Treatment of Extracranial Circulation

Mark H. Wholey, MD, Gustav Eles, MD, Chester R. Jarmolowski, MD, Michael C. L. Lim, MD, Carlos Vozzi, MD, Hugo Londero, MD, Carlos Gadda, MD

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PTA and Stents in the Treatment of Extracranial Circulation

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Investigational or clinically acceptable endoluminal interventions have been extended to essentially all vascular compartments within the body. Most recently, this interest has been extended to involve both the intra and extracranial circulation. Percutaneous methods for intracranial aneurysmal occlusion with detachable coils, embolization methods for obliteration of vascular malformations, and most recently, the establishment of trials for thrombolytic therapy in the acute stroke syndromes are all being evaluated as to both efficacy and safety. Complications, however, need accurate analysis to assess the risk/benefit ratios of these newer procedures. Unfortunately, there is little long-term data to validate efficacy or safety at this time. It would appear that the acute complications for intracranial interventions for aneurysmal involvement can vary from 10 through 30%; 13% complications have been described for embolization of arteriovenous malformations. Thrombolytic therapy for acute stroke syndromes has been associated with reperfusion injury, focal intracranial bleeding, and distal embolization beyond the primary thrombotic site. Unofficial results, however, in the acute strokes with negative CT and positive angiographic findings, and lysis initiated prior to 4-6 hours have been impressive. In our own institution where a significant number of aortocoronary bypass procedures are done, in addition to heavily weighted PTCA volume, patients are occasionally seen with acute stroke syndromes, in whom we have seen rapid resolution of the clot, within 30 minutes, and total resolution within 45 minutes following 750,000-1,000,000 units of urokinase given over a one hour period (Figures 1A-D). These post surgical, and post catheterization cases, however, obviously require better validation from a multicenter trial.

Our experience with the extracranial circulation includes the great vessels originating from the aortic arch, but also the origins of each internal carotids and the vertebrals from the subclavian arteries. Several relatively large angioplasty series have now been reported with embolic complications occurring in less than 2% of the accumulated group. Puncture site hematomas, suboptimal angioplasty, and focal dissection have been

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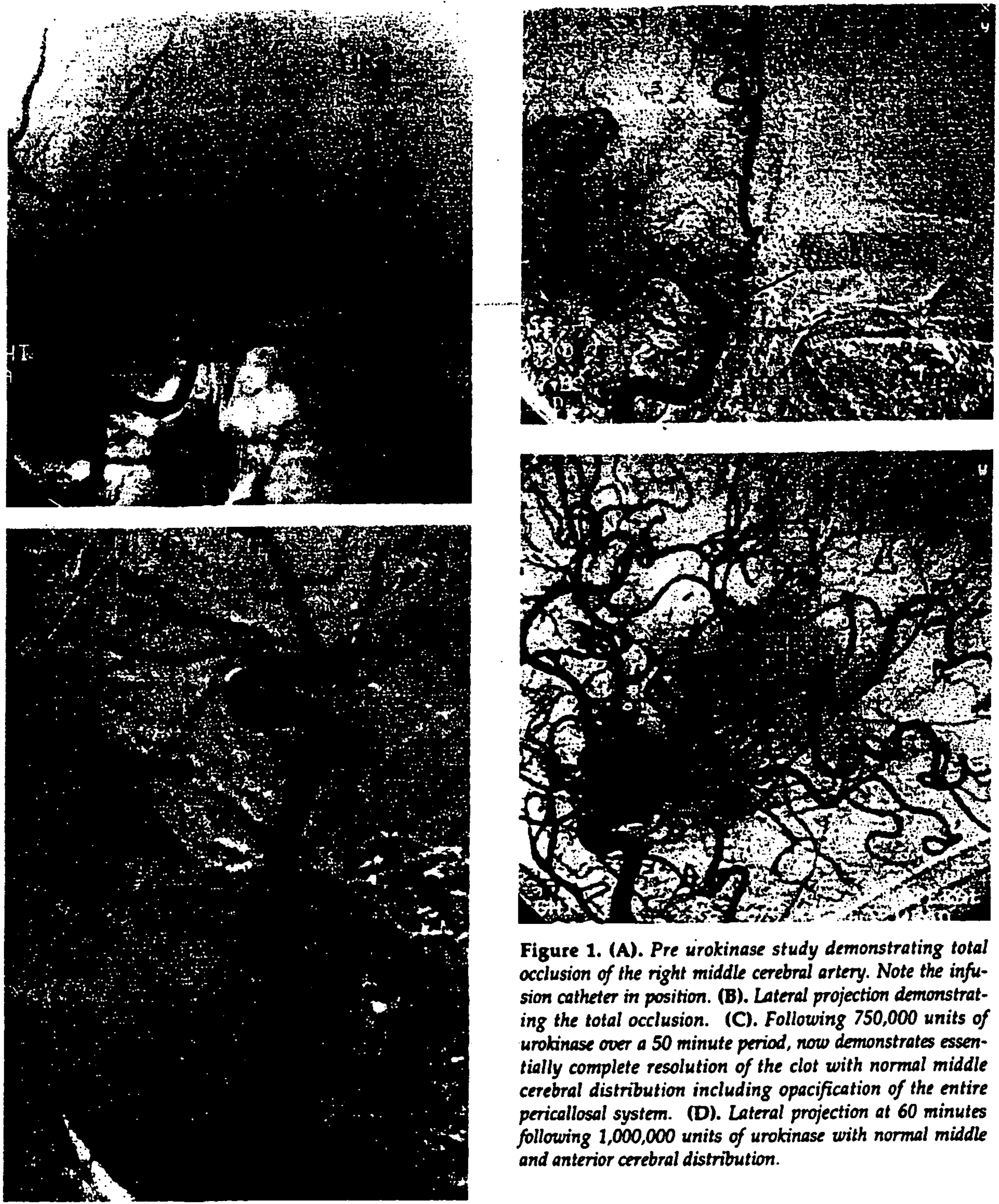

Figure 1. (A). *Pre urokinase study demonstrating total occlusion of the right middle cerebral artery. Note the infusion catheter in position.* (B). *Lateral projection demonstrating the total occlusion.* (C). *Following 750,000 units of urokinase over a 50 minute period, now demonstrates essentially complete resolution of the clot with normal middle cerebral distribution including opacification of the entire pericallosal system.* (D). *Lateral projection at 60 minutes following 1,000,000 units of urokinase with normal middle and anterior cerebral distribution.*

reported in approximately 3.5%. In those patients with suboptimal angioplasty, stents are being used more frequently. The restenosis rates for the great vessels have varied from 2 to 12%. Mathias et al. in their European studies also are reporting complications of less than 2%.[2] Our experience with approximately 174 extracranial PTA and stent procedures not including internal and bifurcation carotid data, reports an embolization rate of 1.5%. In one patient, embolization was to the upper extremities, and this was managed effectively with thrombolytic therapy. Only one

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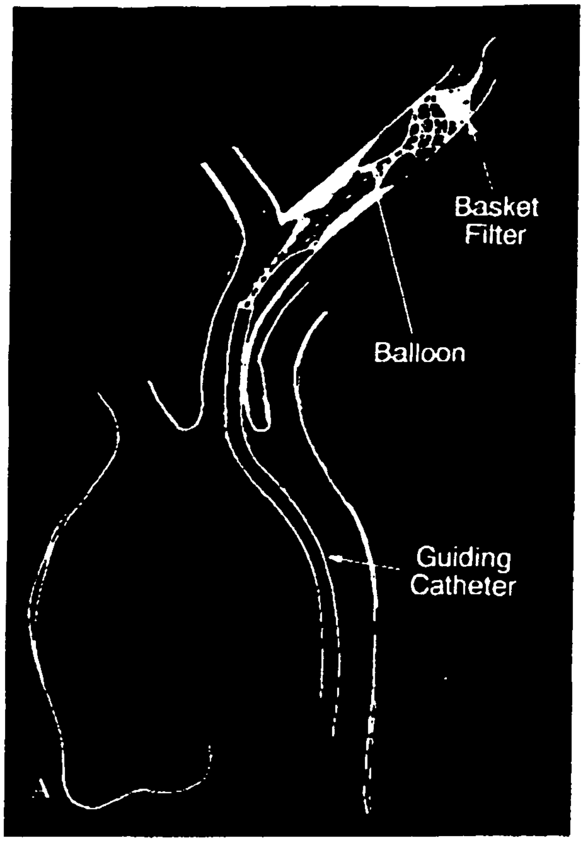

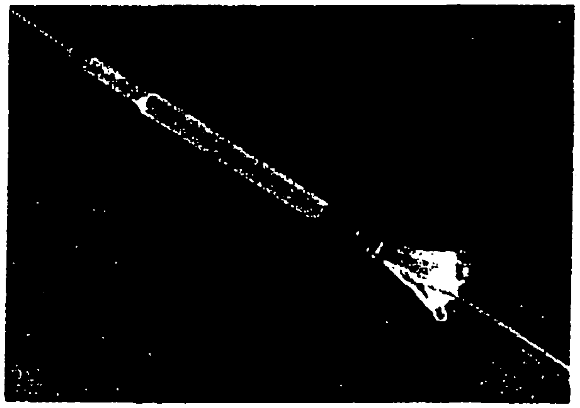

Figure 2. **(A)** *Diagramatic illustration demonstrating the basket filter just distal to the angioplasty balloon passed through the conventional guiding catheter.* **(B)** *Carotid filter demonstrating the balloon activated filter and the polyethylene jacket, both of which are distal to the angioplasty balloon and functioning on an over-the-wire system.*

patient suffered abrupt occlusion of the subclavian that could not be recrossed. Posterior fossa infarction from the vertebral angioplasty has been described, but has not been observed in our series, nor in the European studies by Mathias or Kachel.[4,9]

Clearly, all of the interest, and preliminary experience in the extracranial circulation forms the basis for developing new technology in the management of stenotic changes at the carotid bifurcation, and the internal carotid origins. The largest series reported to date, is by Mathias et al.[2] with 305 patients undergoing PTA for internal carotid stenosis, and a neurologic complication of 2%. Forty-seven patients had Wallstents, with two transient ischemic attacks, but no intracranial infarction, or major emboli noted on follow-up. Twenty-seven patients did, however, have insignificant intimal hyperplasia.[4] Roubin's experience in this country, with now over 100 stents for internal carotid artery stenosis, described an 8% complication rate.[1] Several of those represented TIA's or recoverable minor strokes, although one death was described. Intravascular stents, however, do have their own inherent problems, with restenosis, subacute occlusion, false aneurysms, and embolization all being described. Interestingly, adjunctive methods incorporated into the angioplasty catheter, including externally expandable filters, and flushing techniques, all designed to prevent embolization, have proved more cumbersome than necessary, and presently, most of the successful procedures have been done without adjunctive support (Figures 2A, B). This is not to say, however, that an effective filter may not ultimately be necessary. Theron's experience with 66 internal carotid stents utilizing cerebral flow protection has resulted in no stroke events.[6,7]

In Ellis's review of over 2000 coronary interventions, and our experience in the peripheral circulation, embolization has occurred in less than 1-2%.[5,8,10] If extracranial interventions result in a similar embolization rate, then it is conceivable that a randomized trial against the "gold standard" carotid endarterectomy could be considered. Carotid endarterectomy in an experienced environment has a 1% mortality and a 3% morbidity which is a standard that may be difficult to duplicate. However, these morbidity and mortality figures may not be true in those patients undergoing carotid endarterectomy who have other significant comorbidity. Reports with post operative morbidity approaching 11% have been described. Intravascular stents, because of the ease of application, should not be seriously affected by other comorbid factors (Figures 3A, B). However, accurate placement of the stents at the target lesion involving the internal carotid is critical. Whenever possible, the external carotid should not be overlapped by the stent considering

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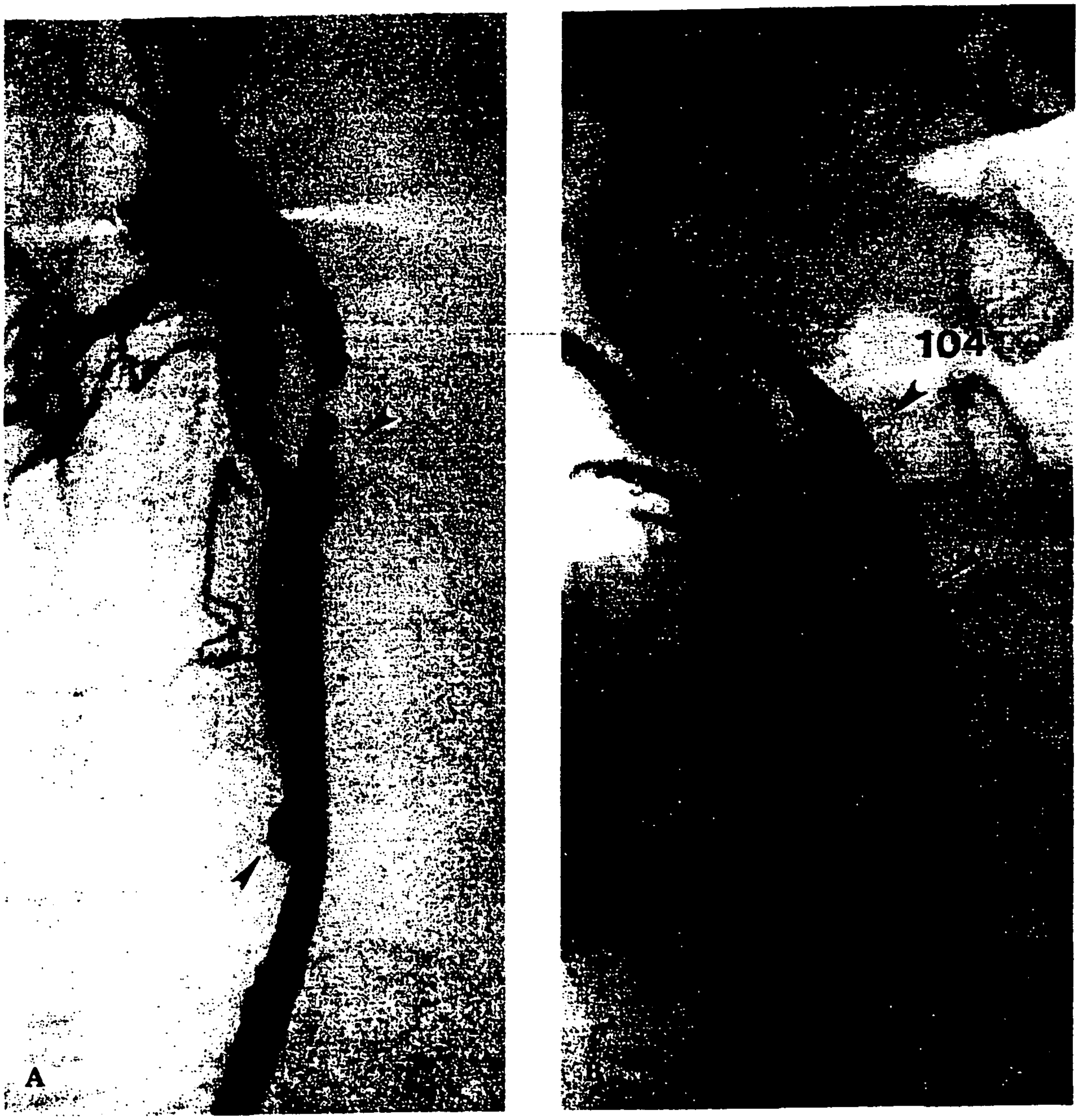

Figure 3. (A) *High grade stenosis existing over a 2 cm segment of the internal carotid with ulceration noted proximally.* **(B)** *Effective dimensions with significant improvement in the contour of the internal carotid following a 2 cm J & J stent expanded to 5 mm.*

the importance of the external carotid as a collateralizing source to both the internal carotid circulation intracranially, as well as, the vertebro–basilar circulation via the collateralization that sometimes exists across the external occipital. The internal maxillary, via the ethmoids and retrograde opthalmic flow, occasionally are critical collateralizing sources for the ipsilateral carotid circulation (Figures 4A, B).

At this time, there is inadequate information available to establish either the role of PTA or intravascular stents for internal carotid artery stenosis. Preliminary results, primarily from Europe, would suggest that a feasibility study may be indicated. The entry criteria for a feasibility study would basically include al those participants who would be enrolled in either the NASCET or ACAS trials. In addition, it could include those patients with inaccessible lesions at the high cervical carotid segment, a select group

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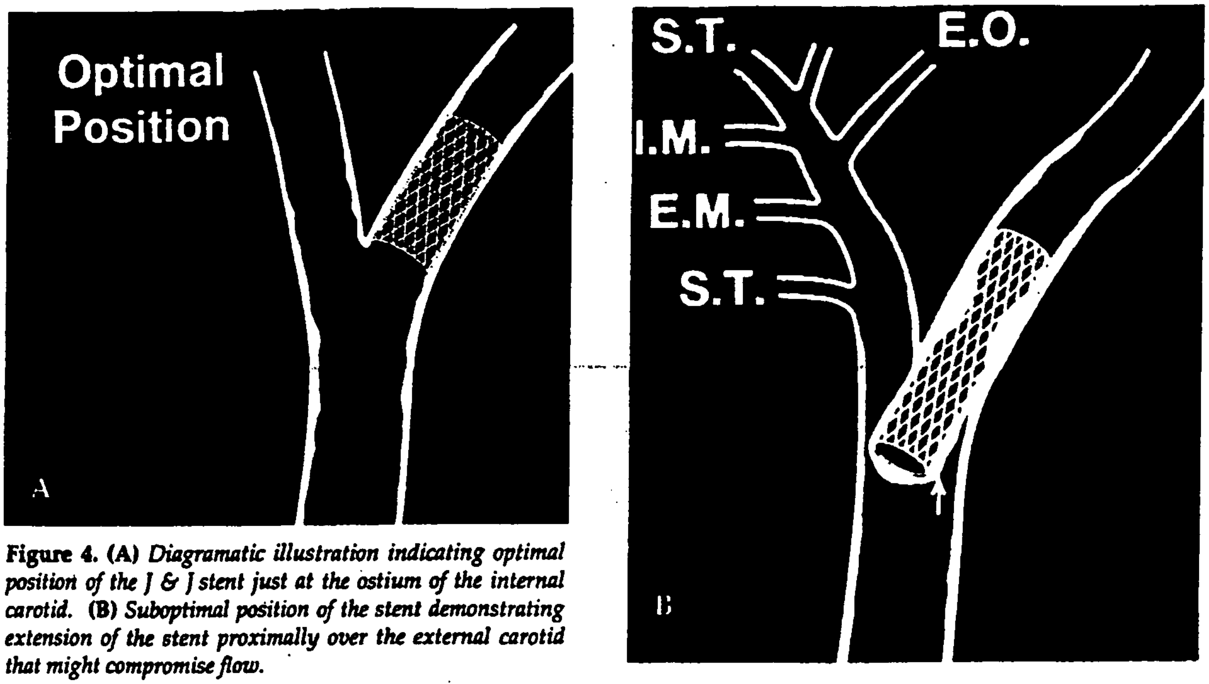

Figure 4. (A) *Diagramatic illustration indicating optimal position of the J & J stent just at the ostium of the internal carotid.* **(B)** *Suboptimal position of the stent demonstrating extension of the stent proximally over the external carotid that might compromise flow.*

with spontaneous dissection, or a subset of patients who have a surgical contraindication. Assuming satisfactory results in the feasibility study, one could then initiate a carefully planned, randomized control against carotid endarterectomy.

This experience at the Pittsburgh Vascular Institute included 174 procedures of which 61 represented carotids, 15 of which were PTA and 46 were stents; 13 vertebrals; 7 innominate, and 81 subclavian, with 10 axillary arteries and 2 grafts, one of which was an internal carotid interpositioned graft. If we separate out the carotid plus the vertebral studies representing 74 procedures, we encountered a complication rate of 7.9%. The 61 patients that had carotid angioplasty and/or stents had a complication rate of approximately 8%. However, 46 patients had a primary stenting procedure. From this group, 2 patients had minor strokes involving upper extremities. One patient had full recovery within 24 hours, and the other had basically 85% recovery at the end of one week with minimal residual hand weakness. Two patients encountered TIA's, 1 of which was a brief 30 second seizure. There were no deaths and no major disabling strokes in the series. Considering that only one of these patients had a non-recoverable stroke with only minimal residual, the morbidity of the procedure in this relatively high risk group of patients with significant comorbidity, is quite acceptable in comparison to surgical standards. Suboptimal results for PTA were 11% and 0% for stenting. The carotid stent group has an average duration of follow-up of only 2.5 months. Twenty-nine of the patients have been reevaluated, with no new onset of neurologic sequelae. In this group, there were not stent deformations noted as evaluated by three dimensional CT angiography and by magnification radiography. All patients have had 24 hour post-operative, and 1 month color flow Doppler evaluation. All patients are required, by the protocol, to undergo 6 month angiographic evaluation. In those few patients that have had bilateral internal carotid stents, we have not noted any significant intimal hyperplasia on the initially placed stents. The second stent is ordinarily placed at 1-2 months following the original deployment. Interestingly, neither morbidity nor technical failures have been related to the characteristics of the target lesion. Ulceration and subtotal occlusions have not resulted in technical failure. Technical failures have resulted from problems in the aortic arch with either ectasia and/or aneurysmal formation or deep seeded innominants arising from the ascending portion of the aorta where guiding catheter access has been difficult.

If we include an extracranial interventions (174)

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we had a technical success of 93% for the early PTA studies, and 94% for the stents, with suboptimal results of 6% in PTA and 0% for stents.

It would appear that the intrathoracic great vessels, including the proximal vertebrals, can be effectively managed by an endovascular procedure. The internal carotid, and its bifurcation, however, are still controversial and the data will need considerably more substance with statistical power from a well controlled feasibility study before being randomized against the gold standard of carotid endarterectomy. This however, should be clarified with the completion of the desirable feasibility study which would include carefully collected and collated data that will be continually analyzed by a Data Safety Monitoring Committee in order to achieve an accurate conclusion.

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